MONROE

Machine Methods

FOR THE EXTRACTION OF SQUARE ROOT

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THE extraction of square root by the arithmetical, long-hand process is tedious and laborious, and errors are frequently made in figuring.

The use of a slide rule or a logarithmic table for square root extraction is fairly fast for those well versed in their use. The slide rule, however, is limited as to the number of digits obtainable in the result, with accuracy assured.

The method for the extraction of square root which is the most simple, speedy, and accurate, regardless of the number of decimal places required, is that employing an adding-calculator. The Monroe method described in the following pages has been in use for twenty years by thousands of business firms, colleges, and engineers.

Monroe Method Described Arithmetically and Algebraically

The Monroe machine method for extracting square root described in detail in these pages is entirely a mechanical process. It can be learned quickly and, once learned, requires no mental effort. It has aroused the interest of hundreds of Monroe users, particularly because of the fact that this mechanical method has a direct relation to the arithmetical or algebraic principle of extracting square root.

The Monroe method of extracting square root can be described as follows:

Arithmetically

After the amount from which the root is to be extracted is placed in the machine, all operations are a matter of the subtraction of the odd numbers. For example, in finding the root of 9, if we subtract the odd numbers successively, we subtract 1, 3, and 5, making a total of 3 subtractions. The sum of the three terms subtracted $(1 + 3 + 5)$ is 9, or the square of 3. Therefore, 3 is the root of 9. Also the last term subtracted, 5, is one less than twice the root $(2 \times 3 = 6)$.

Thus we secure the root mechanically by subtracting the successive terms of this series. The last term subtracted, plus 1, is left on the keyboard (it is twice the root in the upper dials), and must again be subtracted, in the subsequent calculations of the problem, the same number of times as the following parts of the root. We illustrate:

Algebraically

$$(a+b)^2 = a^2+2ab+b^2 \text{ or } a^2 + (2a+b)b$$

Expressed numerically:

$$(46)^2 = (40+6)^2 \text{ or } 40^2 + (2\times 40+6)6$$

Therefore, when the second factor, b, (or succeeding factors) is being subtracted in a manner similar to that of the first, twice the first is also being taken out.

Monroe Automatic Subtraction Method

I—*Decimal Rule—Upper Dials*—Set the decimal marker in the upper dials at the number of decimal places desired in the root. *Keyboard*—Set the decimal marker on the keyboard at the same number of places as that in the upper dials. *Lower Dials*—Number of decimal places to be set off in the lower dials is the sum of those set in the upper dials plus those set on the keyboard.

II—*Grouping*—The digits in the number from which the root is to be extracted are grouped, mentally or physically, in pairs. This is necessary in order to locate the column in which to start setting up the successive odd numbers. If the grouping is done physically use the decimal markers to point off the groups, starting at the decimal point and counting to the left. If the number contains an odd number of digits, for example, 23875, there will be three groups, as follows: *02 38 75*. If the number contains an even number of digits, for example, 4386, there will be two groups, as follows: *43 86*. If the number in the lower dials contains decimals only, the same grouping is made of the decimal digits, starting from the decimal point and counting to the right.

III—*Keyboard Set-up: Odd Numbers*—The following rules govern the first set-up on the keyboard of 1, as the first odd number:

(a) When the number is a whole number, or a whole number and decimals:

Set the 1 in that column of keys to the left of the keyboard decimal marker corresponding to the number of groups of two in the amount in the lower dials. For example, if the lower dials amount has three groups of two digits to the left of the decimal point, the 1 is set in the third row of keys to the left of the decimal marker on the keyboard. If there are two groups of two digits, set the 1 in the second column, etc.

(b) When the number is a decimal:

Set the 1 in the first row of keys to the right of the keyboard decimal marker, provided the first group of two digits in the lower dials amount contains significant figures. If the first group contains only ciphers, set the 1 in the second row of keys, provided the second group contains a signficant figure and not two ciphers.

IV—*Carriage Position*—When the grouping into sets of two digits has been made and the 1 set correctly on the keyboard, the carriage must be positioned as follows before subtraction takes place:

(a) When the amount in the lower dials is a whole number or a whole number and decimal, position the carriage so the 1 already set on the keyboard is directly in line with the right hand digit of the first group of two digits at the left. For example, if the first group in the lower dials amount is 26, place the carriage so the 1 on the keyboard is in line with the 6 of the group 26. If the group is 07, place the carriage so the 1 on the keyboard aligns with the 7 of the group 07.

(b) When the amount in the lower dials is a decimal, place the carriage so the 1 on the keyboard is directly in line with the right hand digit of the first group of pairs containing a significant figure and not two ciphers.

V—*Subtraction Process*—Having positioned the carriage, the next step is the subtraction of successive odd numbers, starting with 1, to secure the root, which will appear in red figures in the upper dials. The following rules apply to the automatic subtraction process:

(a) Using two hands, set up the odd numbers successively with the left hand, and simultaneously depress the minus bar, once for each key set up, with the right hand. For example, set with the left hand, 1,3,5,7,9,11,13, etc., each time making a depression of the minus bar.

(b) Whenever the subtraction cannot be made a bell will ring and a row of 9s will appear to the left of the number in the lower dials. When only one over-subtraction has been made, it is necessary simply to depress the plus bar once to correct the over-subtraction.

(c) After the over-subtraction has been corrected, change the key last depressed to the next lower digit, which is always an even number. Shift the carriage once to the left and, starting with the 1 in the next column to the right, continue subtracting the odd numbers as previously described until the next over-subtraction takes place.

(d) If, in the above processes, the number on the keyboard is 29, or 289, or 3419, and no over-subtraction has yet been made, the next higher odd figure for these numbers is 31, 291, and 3421. Thus it becomes necessary to change the keys set up in the last two columns instead of in the last column only, as is done on most of the subtractions. If three or more of the final digits are 9s, three or more keys will have to be changed accordingly.

(e) Whenever the 1 is set up and the item cannot be subtracted, as indicated by the ringing of the bell, it is then necessary to clear out the 1 with

the single column clear key, and after shifting the carriage one place, be sure to skip that row of keys in making the set up of the next 1.

VI—*General*—If the root has been extracted in accordance with the instructions given, the amount remaining on the keyboard will equal exactly twice the amount of the root in the upper dials. This check for accuracy can be made at any time during the operation.

It is possible to eliminate the over-subtraction in extracting the root by carefully watching the lower dials to see whether the amount on the keyboard can be subtracted. It is rather difficult to do this, however, particularly with large numbers, and is not nearly so mechanical nor automatic.

When the root has been found, represented by the red figures in the upper dials, clear the keyboard only. Place the root on the keyboard and multiply by the amount in the upper dials. If the root is correct, the upper dials will clear to ciphers and the lower dials will show the amount originally placed there.

Example—Automatic Subtraction Method

I—*Whole Number and Decimals*

Example: $\sqrt{73083.6809} = 270.3399$

Decimal Set-up for Root of four decimal places:

Upper Dials	4
Keyboard	4
Lower Dials	8

Repeat Key Locked Down

Use same decimal ratio for roots to other required decimal places.

Step 1. With Carriage in "5" position, set 73083.6809 on keyboard at decimal. Depress plus bar once. Touch master clear key and minus bar simultaneously.

2. An inspection of the whole number in the amount in the lower dials shows three groups of two digits each, as follows: *07 30 83.*

3. Set 1 in seventh column on keyboard, or in third row to left of decimal marker. Place carriage in "7" position so that the 1 in the keyboard is directly aligned with the 7 in the lower dials, which is the right hand digit of the first group, 07.

4. With left hand setting keys and right hand simultaneously depressing minus bar, subtract successively the odd figures in the series, i.e. 1,3,5, etc., until the bell rings for over-subtraction.

5. Bell rings when 5 has been subtracted. Depress plus bar once. Change 5 key to 4. Set 1 in sixth row on keyboard. Move carirage to "6" position. Keyboard now shows *41*0.00000.

6. Depress odd keys successively in sixth row, subtracting each one. 9 key is depressed and subtracted, and bell does not yet ring. Keyboard shows *490*. Change keyboard set-up to *510*. and subtract. Still there is no over-subtraction. Continue subtracting *530* and *550*. Then the bell rings. Depress plus bar once. Change 5 in sixth column to 4. Shift carriage to "5" position. Place 1 in fifth column. Keyboard now reads 541.0000.

7. On the first subtraction in fifth column the bell rings. Depress plus bar once. Change 1 key in fifth column to 0 by depressing single column clear key. Move carriage to "4" position and set 1 in fourth column. Keyboard now reads 540.1000 and upper dials show 270.0000.

8. Continue by same procedure to subtract odd numbers. Over-subtraction takes place on 7 in the fourth row. Correct. Move carriage to "3" position. Place 1 in third row. Keyboard reads 540.6100.

9. Continue procedure until "1" position of carriage is reached. Upper dials show in red figures 270.3399, the square root of 73083.6809. Lower dials read 1936799, remainder. Keyboard shows 540.6798, which is twice the amount of the root in the upper dials.

10. To prove the root, clear keyboard only. Copy to keyboard from upper dials, 270.3399. Multiply with plus bar by red figures, 270.3399. Upper dials clear as proof of correct multiplier and lower dials show 73083.6809, original amount placed there in Step 1, proving that square root, 270.3399, is correct.

II—*Decimal*

Example: $\sqrt{.6835} = .8267$

Decimal Set-up for Root of four decimal places:

Upper Dials	4
Keyboard	4
Lower Dials	8

Repeat Key Locked Down

Step 1. With carriage in "5" position set .6835 on keyboard at decimal. Depress plus bar once. Touch master clear key and minus bar simultaneously.

2. The first group to the right of the decimal in lower dials contains significant figures. Therefore, set 1 in the fourth column on the keyboard, or first row to right of decimal. Place carriage in "4" position so that 1 on keyboard aligns with 8, or right hand digit of first group, 68.

3. As directed in Example I, subtract odd numbers. Over-subtraction takes place when keyboard reads 1.7000. Correct to 1.6000. Upper dials

read .8000. Move carriage to "3" position and set 1 in third row on keyboard. Amount on keyboard is now 1.6100.

4. Continue same procedure to "1" position of carriage. Upper dials show in red figures .8267, square root. Lower dials show 6711, remainder. Keyboard amount is 1.6534, which is exactly twice the root, .8267, in upper dials.

5. To prove the root, clear keyboard only. Set .8267 on keyboard. Multiply by .8267 with plus bar. Upper dials clear to zero, proving correct multiplier was used. Lower dials show .6835, original amount placed in lower dials in Step 1, proving root, .8267, is correct.

Monroe Automatic Inspection Method

I—*Decimal Rule*—Same as for Automatic Subtraction Method.

II—*Grouping*—Same as for Automatic Subtraction Method.

III—*Carriage Position*

(a) *Whole Number and Whole Number and Decimals* — Starting with carriage in the position in which the keyboard and the lower dials decimal markers align, move the carriage to the right, to the position corresponding to the number of groups in the amount in the lower dials to the left of the decimal point. For example, if the amount in the lower dials is 642.68, there are two groups to the left of the decimal point, *06 42*. Therefore, the carriage is moved once to the right so that it is in the second position to the left of the upper dials decimal.

(b) *Decimals*—If the lower dials amount is a decimal, place the carriage so the keyboard and the lower dials decimal markers align. Then move the carriage one place to the left, if the first group of digits in the amount in the lower dials contains significant figures. For example, if the amount in the lower dials is .4285, the first group contains significant figures, therefore the carriage will be moved to the left one place, or to the first position to the right of the upper dials decimal point.

IV—*Inspection Process*—With the carriage in position, proceed to extract the root by the automatic inspection method.

(a) Estimate what number will produce the nearest square less than the amount of the first two digits in the first group. Set that number on keyboard directly under right hand figure of first group and subtract the estimated number of times.

(b) Double keyboard amount and change keyboard set-up to that amount. Shift carriage one place to the left.

(c) Estimate number of times keyboard amount will go into lower dials amount directly in line with keyboard amount. Set estimated number on keyboard in next vacant column to the right of keyboard amount and subtract the estimated number of times.

(d) Increase keyboard amount by an amount equal to the right hand digit of keyboard set-up. Shift carriage one place to left.

(e) Estimate again the number of times keyboard amount will go into lower dials amount directly in line. Set that number in next vacant row to the right on keyboard and subtract the amount that number of times. Increase keyboard amount by an amount equal to the last right hand digit on keyboard. Shift carriage to left one place and continue same routine until "1" position of carriage is reached.

Example—Automatic Inspection Method

Example—Automatic Inspection Method

$\sqrt{642.68} = 25.3511$

Decimal Set-up for Root of four decimal places:

Upper Dials	4
Keyboard	4
Lower Dials	8

Repeat Key Locked Down

Step 1. With carriage in "5" position, set 642.68 on keyboard at decimal. Depress plus bar once. Touch master clear key and minus bar simultaneously.

2. By inspection we note there are two groups in lower dials amount to left of decimal, *06 42*. Therefore, we move carriage to "6" position or second place to left of upper dials decimal.

3. The first group is 06. We note that 2 will produce the nearest square to 6, therefore we set 2 on the keyboard in the sixth column, or directly under the 6 in the lower dials, and depress minus bar twice.

4. Change keyboard amount to 4, or double the 2, making keyboard read 40.0000. Move carriage one place to left or to "5" position. We estimate 4 on keyboard will go into 24 (in line in lower dials) approximately 5 times. Set 5 in fifth column, making keyboard read 45.0000. Subtract five times. Lower dials now read 17.68000000.

5. Increase 45. on keyboard by amount of last digit, 5, changing keyboard set-up to 50.0000. Shift carriage to "4" position.

6. We estimate 5 will go into 17 in lower dials 3 times. Set 3 in fourth column on keyboard, making keyboard set-up now 50.3000, and subtract three times. Lower dials now read 2.59.

7. Increase 50.3 on keyboard by amount of last digit, 3, making keyboard set-up 50.6. Shift carriage to "3" position.

8. We estimate that 5 will go into 25 five times. Set 5 in third column on keyboard. Keyboard now reads 50.65. Subtract five times. Lower dials now read .0575.

9. Continue same process to position "1" of carriage. Upper dials show in red figures 25.3511, square root. Lower dials show 172879, remainder. Keyboard shows 50.7022, which is exactly twice the root, 25.3511, in upper dials.

10. To prove the root, clear keyboard only. Set 25.3511 on keyboard, amount in red figures in upper dials. Multiply by that amount. Upper dials clear as proof that correct multiplier was used. Lower dials show 642.68, amount placed in lower dials in Step 1, as proof that 25.3511 is correct square root.

Monroe Automatic Subtraction and Division Method

I—*Decimal Rule*—Same as for Automatic Subtraction Method.

II—*Grouping*—Same as for Automatic Subtraction Method.

III—*Carriage Position*—Same as for Automatic Subtraction and Inspection Method.

IV—*Division Process*

(a) This method can be used whether the square root is being extracted by the Automatic Subtraction or the Automatic Inspection method previously described. Either of those methods must first be used before the Automatic Subtraction and Division method can be started.

(b) After starting the extraction of square root by either of the previous two methods, it is possible to finish the problem by straight or automatic division.

(c) The division process can be used only when the number of unfilled digits in the upper dials is one less than the number of digits that are filled. For example, if there are four decimal places in the upper dials and the dials which have been filled with figures by the subtraction or inspection process show 243.4000, you will note there are 3 unfilled dials and 4 filled dials. In other words, the number of unfilled dials is one less than the number of filled dials and it is then possible to divide by straight or automatic division, the amount in the lower dials by the amount remaining on the keyboard, to carry out the root for three more digits.

Example—Automatic Subtraction and Division Method

$\sqrt{46032.5806} = 214.5520$

First use the Automatic Subtraction method, then the Division method.

Decimal Set-up for Root of four decimal places:

Upper Dials	4
Keyboard	4
Lower Dials	8

Repeat Key Locked Down

Step 1. Using the Automatic Subtraction method previously described, extract the root up to and including the "4" position of the carriage.

2. Upper dials then read 214.5000, lower dials 22.33060000, keyboard 429.0100.

3. There are three unfilled upper dials and four filled dials. Therefore, straight or automatic division can now be used to secure the three remaining digits of the root.

4. Place the carriage in the "3" position and divide.

5. Upper dials show in red figures 214.5520, the square root. Keyboard amount is still 429.0100, which in this method is not twice the root, as in other methods. Lower dials show .02208000, remainder.

6. To prove, clear keyboard only. Copy to keyboard, red figures in upper dials, 214.5520. With plus bar multiply by that amount. Upper dials clear, proving that correct multiplier was used. Lower dials show 46032.58278400, which is very nearly the same amount as that set into the lower dials in Step 1 — 46032.5806. Therefore, the root is correct.

The Monroe method of extracting cube and higher roots is explained in detail in a separate booklet, Form 720-S.

For further instructions or help with any figuring problems, Monroe users are invited to get in touch with our nearest sales office. We maintain branches in all the principal cities in the country and Monroe representatives are qualified to recommend the most efficient methods for the handling of figure work. The Accounting Service Department, located in the General Offices at Orange, N. J., also welcomes the opportunity to be of service to users.

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